18.3: Rendering Digital Cinema and Broadcast TV Content to Wide Gamut Display Media

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Abstract

Much more is possible in achieving brighter, more vibrant colors for a richer visual experience in emerging, wide-gamut display media. Yet, both digital cinema and broadcast TV content fall well short of this promise. In this paper, we provide the means for realizing this promise by identifying certain memory colors (e.g., green grass, red, and blue sky) and rendering each independently making use of the full gamut of the display media while identifying and maintaining flesh tones to their original intent. Further, a means is provided for extending the gamut of not just wide-gamut, but any display media by simply lowering the white point of the display.

1. Background and Objective

In emerging display media technologies, e.g. wide-gamut, LED backlight displays, much more is possible in achieving brighter, more vibrant colors for a richer visual experience. Yet, both digital cinema and broadcast TV content are based in standards1,2,3 whose gamut falls well short of this promise. And attempts to globally expand this content out to the brighter, more colorful primaries of wide-gamut displays have been met with the hue and cry of unnaturalness4. Have we been so conditioned to these standards - most of us since childhood - that we consider video and cinema as a separate reality from what we see every day? This paper asserts that perhaps not, that it is instead a matter of rendering. That certain features of a scene – specifically flesh tones and perhaps certain object or surface colors - should be rendered as original while other features such as a blue sky on a crisp winter’s day, a sunset, or a colorful arrangement of flowers are clear candidates for brighter, more colorful renderings.

2. Methods and Results

A number of tools5,6,7,8 are available for rendering digital cinema and broadcast TV content to wide gamut display media under given conditions of intent. In this paper, that intent is to identify certain memory colors (e.g., green grass, red, and blue sky) and render each independently making use of the full gamut of the display media while identifying and maintaining flesh tones to their original intent and maintaining luminance. This is carried out by an application of sigmoidal-like transformations on the color attributes in a linear appearance space like CIELAB9 and, as light and dark adaptation are modeled in such spaces, mediating the perceptual gamut of a display media as a function of its surround or viewing conditions.

2.1. The transformation in IPT space

The appearance space CIELAB has reasonable perceptual uniformity in chroma, but is less than uniform in hue particularly in the reds and blues. Hence, the appearance space IPT10, a appearance space based in opponent color theory, was chosen as perceptually uniform in hue. Figure 1 illustrates plane of constant hue for a particular display in Luminance L, analogous to intensity I in IPT space, and chroma C as the geometric distance from neutral to a color value at constant intensity.

The vector shown at L_in = L_out illustrates the rendering of a chroma value C_in to C_out according to $C_out = \alpha C_{max}$ where $C_{max}$ is the maximum chroma of the particular display at $L_{in} = L_{out}$ and $\alpha$ is a sigmoidal-like function of the input chroma value given by:

$$\alpha = V_2 + \left( \frac{C_{in}}{C_{max}} \right)^{\gamma} \left( V_1 + 1 \frac{C_{in}}{C_{max}} \right)^{\gamma}$$

(1)

for $V_1$ and $V_2$ the gain and offset of the sigmoidal and $\gamma$ the gamma-like exponent independently prescribed for each color value given the rendering intent. Examples of the application of this transform are given in the following.

Figure 1: A plane of Constant hue in IPT space for a particular display

Figure 2: The distribution of sigmoidal exponent in chromaticity space as mediated by certain memory colors
2.2. Rendering certain memory colors

The memory colors for green grass, blue sky and reds offer opportunity for demonstrating the benefits of wide gamut displays. Their respective Gaussian-like distributions in chromaticity space, illustrated in Figure 2 against relative exponent $\xi$, are derived from a cluster analysis of many digital cinema scenes.

Figure 3: Three successively more aggressive levels of rendering input chroma to the full available gamut. The red curves are applied to blue skies, the blue to red and green grass, and the green to the remainder.

(a) Level 1
(b) Level 2
(c) Level 3

Figure 4: The results of applying the levels of rendering shown in Figure 4 to the original (Figure 5)

(a) Level 1
(b) Level 2
(c) Level 3

2.3. Maintaining flesh tones

In a similar cluster analysis, a normal probability distribution in chromaticity space for the occurrence of flesh tone was constructed as illustrated in Figure 6.

Figure 5: Original image

In Figure 3, the exponent is applied at three successive levels of aggressiveness in the rendering of input to output chroma in IPT space. Within each level, the least aggressive curve shown in red is applied to blue sky (shown as a relative $\xi$ of -1 in Figure 2), the blue curve to red and green grass (a relative $\xi$ of +1), and the green curve as a baseline level for all other colors (a relative $\xi$ of zero). Figure 4 illustrates the results for a highly colorful scene of flowers whose original is shown in Figure 5.
Figure 7: The results of maintaining or preserving flesh tones

The rendering to the full gamut of available chroma described in the above is then mediated by $C_{out} = WC_{in} + (1 - W)C_{max}$ where the weighting function $W$ is simply the probability of the occurrence of flesh tone. If the probability is high, chroma will be maintained. If the probability is low, chroma will be rendered to the wider gamut. Figure 7 illustrates the results of employing this strategy.

2.4. An expansion of perceptual gamut

The powers of adaptation by the human visual system are exploited to expand the perceptual gamut of any display media, not just wide gamut displays, by simply “pushing down” the white point thereby extrapolating a gamut expansion in perceived lightness, chroma, brightness, and colorfulness (see ref. 6 for a complete description of this methodology). Figure 8 illustrates this method. The inner gamut represents a baseline display whose white point is set to maximum brightness. Each succeeding gamut represents a successive halving of the white point and assumes that the observer fully adapts. Figure 9 illustrates a striking result of this strategy. In both images, the white point is assumed to be the brighter spot of snow on the mountain. In the image on the left, the white point is set to the maximum brightness of the display [as is typically the case]. On the right, the maximum brightness of the display is four (4) times the brightness of white.

Figure 9: The effect of expanding the perceptual gamut by simply lowering the white point.
3. Impact

Implementation of these strategies in the consumer display media market has proven to be costly requiring, at a minimum, 3-dimentional look-up tables in RGB with high dimensionality capable of independent control of color and operating at video rates. However, like the display media technology, memory and processor technology continue to evolve to the point of being affordable. Given the current state of this technology, a rendering strategy that provides brighter, more colorful renderings in the wide gamut display media that remains faithful to the critical regions of color intent and targeted to the chosen regions of gamut is imminently possible.

To this end, an specific implementation of these strategies referred to as eeColor® has been just recently released as a product by Entertainment Experience, LLC. This initial release is directed at home theater markets in a set-top box. The rendering intent for this product has been to provide a consistent, high level viewing experience over the range of home theater-like dark, dim, and normal (room lighting) viewing conditions, yet take full advantage of the opportunities provided by the wide-gamut display media available in this market. In the future, as display media manufacturers and content providers wish to even further discriminate their products, such technology can provide an almost endless set of tools and flexibility for providing an unique product identity that distinguishes their products.

4. References


